



October 4, 2021

BY ELECTRONIC FILING

Karl A. Kensinger
Chief, Satellite Division
International Bureau
Federal Communications Commission
45 L Street, N.E.
Washington, DC 20554

Re: *IBFS File No. SAT-MOD-20200417-00037*

Dear Mr. Kensinger:

Space Exploration Holdings, LLC (“SpaceX”) hereby responds to your letter¹ requesting additional information about the semi-annual report SpaceX filed on July 1, 2021, on the status of its Starlink non-geostationary orbit (“NGSO”) satellite constellation.² SpaceX proactively volunteered to report on the health of its system, first, because it believes transparency is critical to sustainable space operations and, second, to address misrepresentations about the performance of Starlink satellites. While SpaceX alone submits this response as part of its commitment to radical transparency about space operations, SpaceX urges the Commission to explore ways to ensure that the public is given a more accurate picture of all space operations, to include the universe of non-U.S. satellite systems that enjoy access to the U.S. market.³

No operator can meaningfully improve the operational environment of space alone. Despite repeated pleas for other NGSO operators—including those that have chosen to license their satellites outside the United States and claim not to be bound by U.S. rules yet enjoy the benefits of U.S. market access—to provide similar public disclosures about the performance of their satellites, none have followed SpaceX’s lead on transparency. Indeed, while SpaceX is providing detailed information about the status of individual satellites, other NGSO operators do not provide the Commission or the public at large any status updates at all, even when a satellite in their system has suffered an anomaly posing much greater risk than SpaceX’s low-altitude operations. In fact, some operators that have opposed Commission oversight and transparency for their non-U.S. systems are simultaneously misrepresenting information that SpaceX has provided to explicitly campaign internationally against the Commission and U.S. operators. Other non-U.S. operators have used the Commission’s public docket to question the adequacy of SpaceX’s collision avoidance system, while privately asking to rely on SpaceX’s system to limit the risk of collision that their own system may cause.

¹ See Letter from Karl A. Kensinger to William M. Wiltshire, IBFS File No. SAT-MOD-20200417-00037 (Aug. 19, 2021).

² See Letter from David Goldman to Marlene H. Dortch, IBFS File No. SAT-MOD-20200417-00037 (July 1, 2021).

³ See Petition for Reconsideration of Space Exploration Technologies Corp., IB Docket No. 18-313 (Sep. 24, 2020) (“SpaceX Petition”).

A failed satellite at higher altitudes than SpaceX will remain in orbit for decades or centuries longer than SpaceX satellites, but the public is left in the dark about these risks. Because only SpaceX is providing the sort of information contained in its semi-annual report and this follow-up letter, the public may develop a false impression about the true risks of systems at these higher orbits as compared to the well-recognized relative safety of orbits below 600 km where SpaceX operates.

By giving the public a more accurate picture of operations in space, the Commission can also help facilitate a more informed and robust discussion of proper policy. For instance, in response to a request from the National Science Foundation, the independent advisory group JASON strongly commended SpaceX for its recent modification to operate its satellites below 600 km, while simultaneously recommending against licensing operations at higher altitudes until “extremely stringent requirements on the post mission disposal probability have been demonstrated.”⁴ JASON further recommended that all satellite operators publish ephemerides.⁵ Critically, the recommendation was not limited to just specific U.S. operators. The Commission should consider whether to extend inquiries to all operators consistent with these recommendations.

SpaceX urges the Commission to explore ways to ensure that the public is given a more accurate picture of all space operations, rather than a distorted view based on the unilateral disclosures made by only one U.S. licensee. One critical step to create this fuller perspective would be for the Commission to act promptly on SpaceX’s pending petition for reconsideration to extend the orbital debris mitigation rules to include non-U.S. systems that access the U.S. market.⁶ Only with all operators working together and providing crucial information to each other and the public at large can we truly maintain the space environment for future operations and human space flight.

Below we set forth each of your questions and our responses in turn.

- 1. SpaceX identified Starlink 1881 as a satellite that was screened from future deployment or removed from operations, and which is not maneuverable for purposes of collision avoidance. According to public sources, Starlink 1881 appears to be located at an altitude of approximately 480 km. The semiannual report, however, did not include Starlink 1881 in the list of satellites that have experienced disposal failures. The Third Modification Order defines a disposal failure as a satellite which “loses the capability to maneuver at a higher altitude [above its insertion altitude of 350 km or below], as this identifies satellites that present collision risks that are anomalous.” Please address why Starlink 1881 was not included on the list of satellites that have experienced a disposal failure, and if it has experienced a disposal failure as defined in the Third Modification Order, please provide a discussion of assessed causes and any remedial actions SpaceX has taken.***

⁴ JASON, *The Impacts of Large Constellations of Satellites*, National Science Foundation 109 (Nov. 2020, updated Jan. 21, 2021), https://www.nsf.gov/news/special_reports/jasonreportconstellations/JSR-20-2H_The_Impacts_of_Large_Constellations_of_Satellites_508.pdf.

⁵ *Id.* at 111.

⁶ See SpaceX Petition, *supra* n.3.

The semi-annual report noted in Section 2 both that Starlink-1881 was removed from operation for the purpose of disposal and that it was unable to propulsively maneuver. Unfortunately, the report failed to include it under Section 4. This was in error; Starlink-1881 should have also been included in Section 4, in the same row as Starlink-1847. Further discussion of the root cause and remedial actions for this satellite is provided in response to Question 4 below.

- 2. Similarly, Starlink 1847 is listed both as a satellite that has been screened from future deployment or removed from operations and as a satellite which has experienced a disposal failure. According to public sources, Starlink 1847 is no longer in orbit. Please provide any updates concerning the status of Starlink-1847.***

SpaceX identified Starlink-1847 as having a propulsion issue. Upon identification of this issue, the satellite initiated deorbit burns. It was not able to complete propulsive deorbit, as it ran out of propellant on April 4, 2021, at an altitude of 380 km. Following three months of passive deorbit, it re-entered the atmosphere on July 14, 2021 (i.e., after SpaceX submitted its report).

- 3. Please provide additional information regarding the Starlink 1155 satellite which SpaceX lists as capable of maneuvering for purposes of collision avoidance based only on attitude control. Is this satellite still capable of using SpaceX's automated collision avoidance system? How effective is this maneuver capability in mitigating risk and are the threshold's (sic) for maneuver and mitigation the same as for satellites with a propulsion capability? For example, is this capability effective for mitigating risk for conjunction notices less than 48 hours before a possible collision? When is this satellite expected to re-enter the atmosphere?***

The Starlink automated collision avoidance system exports high-fidelity propagations based on satellite GPS ephemeris to the 18th Space Control Squadron for conjunction screening. It downloads Conjunction Data Messages generated by these screenings and distributes them to Starlink satellites accordingly. Starlink satellites leverage this conjunction information to autonomously take risk-mitigating actions. On satellites with healthy propulsion systems, this takes the form of a collision avoidance maneuver in appropriate circumstances. In the case of unhealthy propulsion systems, such as for Starlink-1155, the vehicle is still able to reduce collision risk by autonomously reorienting itself to minimize its cross-section to the encounter (called "ducking"). Because of the Starlink design, this reorientation can reduce cross-sectional area by an order of magnitude.

In addition to being able to preferentially orient themselves at the time of closest approach, non-propulsive Starlink satellites can further leverage their shape by adopting different flight profiles to augment their ballistic coefficients. Satellites have the ability to maintain a "knife-edge" low-drag mode as well as a "barn-door" high-drag mode during the time leading up to a conjunction. These different pointing modes can enable them to modify their radial/along-track offset at the time of the encounter, moving in the direction which minimizes risk.

Moreover, satellites that experience thruster issues but have otherwise healthy propulsion avionics still retain the ability to vent their propulsion tank in a "cold-gas thruster" mode. This method, while less efficient than nominal ion propulsion, can still be used to induce substantial radial and along-track separations, and is valuable for collision avoidance.

All three methods can be effective in mitigating risk and leveraged within 48 hours, with the caveat that drag-based methods are less efficient at higher altitudes where the atmosphere is less dense. Vehicles will autonomously perform attitude based "ducking" when collision probability exceeds $1e-6$. Differential drag and tank venting actions are currently not automated, and instead are evaluated by human controllers on a case-by-case basis.

Starlink-1155 became anomalous, but in its operational orbit. It is expected to re-enter the atmosphere within five years, as originally contemplated. Demise time extrapolations based on decay trends from recent months are inaccurate for two reasons: drag grows exponentially with decreasing altitude, and solar cycle activity is currently at a local minimum. Accordingly, Starlink-1155's decay rate will increase significantly in upcoming years.

- 4. Please provide more detailed information regarding the causes of disposal failures and the remedial actions SpaceX has taken. In particular, for the identified cause, the semi-annual report identified the particular subsystem or component, without specifying the specific failure mechanism. Please also indicate whether the identified causes are ones for which other spacecraft could be at risk of failure, and if so, discuss in greater detail implications for possible failure rates of other spacecraft, whether already in orbit or planned for future launch, any mitigation measures taken with respect to other satellites, etc. Please also provide the dates these satellites failed and the length of time these satellites were operational before failure.***

Starlink-1155

Starlink-1155 experienced a propulsion anomaly on December 25, 2020, 331 days into operation. SpaceX has reduced the powered duty cycle for the propulsion avionics on a satellite from 100% to 6%, thereby mitigating this issue for Starlink satellites. In the eight months since this software mitigation has been deployed, we have not seen the failure mode repeat and for the v1.5 and future generation of satellites, a redesign addresses this issue.

Starlink-1847, Starlink-1881

Starlink-1847 and Starlink-1881 experienced propulsion tank issues. Deorbit operations for these satellites began on February 14, 2021, 94 days into operation, and February 27, 2021, 81 days into operation, respectively.

Operationally, measures were implemented to screen the rest of the already launched fleet for this condition. For all v1.0 satellites manufactured after this condition was identified, additional production screens were added, and the component was redesigned for v1.5.

Starlink-1939

Starlink-1939 became power negative on March 19, 2021, 114 days into operation. Multiple software and operational mitigations have been implemented to protect the v1.0 satellites from this condition, primarily a software update and a design change that was introduced during v1.0.

5. *Please also provide any identified causes of failure and remedial action SpaceX has taken regarding the satellites which were screened from future deployment or removed from operations.*

Satellites have been screened from deployment for two reasons:

1. *Solar array deployment mechanism failures:* Partially deployed solar arrays result in a vehicle geometry that is not controllable for orbit raise or desirable to raise due to limited power generation. The solar array deployment mechanism has been modified for v1.5 to reduce the probability of a partial deployment.
2. *Avionics failures preventing controllability in a high drag environment:* These failures have primarily been one-off manufacturing escapes that have been addressed with production controls and did not affect later Starlink launches.

Satellites have been removed from operation for two reasons:

1. *Unable to perform desired network functions:* When a satellite is not able to perform desired network functions, the responsible action is to deorbit it.
2. *Satellite has reached end-of-life thresholds:* When power generation or propellant mass reach deorbit thresholds, the satellites are removed from orbit.

If you have any questions, please do not hesitate to direct them to me.

Sincerely,

/s/ David Goldman

David Goldman
Director of Satellite Policy

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